A 60-Foot Diameter Parabolic Antenna for Propagation Studies*

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A solid-surface parabolic antenna, sixty feet in diameter and of aluminum construction, has been erected on a hilltop near Holmdel, New Jersey. This antenna can be steered in azimuth and elevation and was specially designed for studies of beyond-the-horizon radio propagation at frequencies of 460 mc and 4,000 mc.

The electrical properties of the antenna and the technique of measurement are described; construction and mechanical details are discussed briefly.

INTRODUCTION

Studies in recent years have demonstrated that transmission of useful amounts of microwave energy is possible at distances considerably farther than the horizon.[1] The exact mechanism responsible is not as yet completely understood, although scattering by atmospheric irregularities seems to play a significant part. A program to study the nature of these effects has been started at the Holmdel Laboratory. An important and necessary tool for this work is a steerable antenna having unusually high gain and narrow beam width. Such an antenna has been built, and it is the purpose of this paper to describe its design and the methods used to measure its radiation properties.

DESCRIPTION OF THE ANTENNA

The antenna is a 60-foot diameter paraboloid made up of forty-eight radial sectors, each constructed of sheet aluminum. Each sector is held to the correct doubly-curved surface by reinforcing ribs, and all are fastened to a central hub eight feet long and thirty inches in diameter. During assembly, the axis of the paraboloid was vertical; thus no scaf-

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[1] Proc. I.R.E., October, 1955, contains many papers by workers in this field.

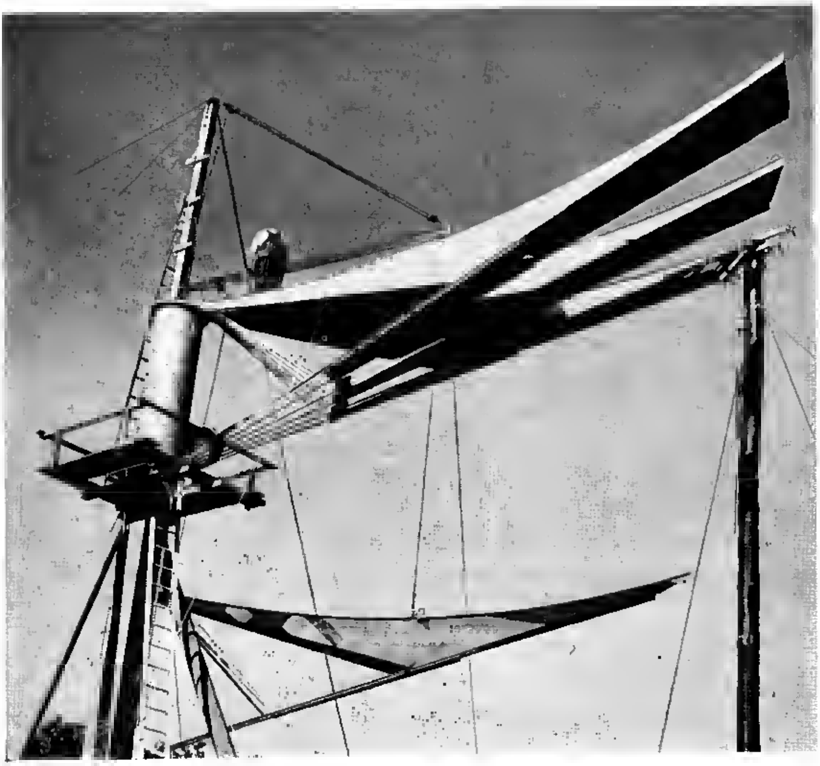

Fig. 1 — Fastening the radial sectors to the hub.

folding was required. Figs. 1 to 5 illustrate the paraboloid construction and support. The weight of the antenna is carried on a vertical column which is mounted on bearings to permit movement in azimuth. The column is held upright by a tripod structure. The central hub of the paraboloid is fastened to a steel girder which extends to the rear along the paraboloid axis and is pinned to a yoke carried by the vertical column, thus permitting movement in elevation. The antenna is scanned by two motors mounted on an A-frame and connected to the end of the axial girder by crank mechanisms. The total scanning range of the antenna is about 3° in both azimuth and elevation.

The antenna is designed for use at frequencies of 460 mc and 4,000 mc. The tolerance on the parabolic reflecting surface is set by the higher frequency and thus must be $\pm\frac{3}{16}$ inch to meet the usual $\pm\lambda/_{16}$ criteria. The focal length is 25 feet, so that the total angle intercepted by the paraboloid as seen from the focal point is 124°. Design of a feed horn for

this angle so that the illumination is tapered to -10 db at the edge of the paraboloid is not difficult; the horn used is diagramed in Fig. 6, with dimensions given in wave-lengths. The feed horn is mounted in a tripod support extending out from the front surface of the paraboloid. It is made strong enough so that two 460 mc horns can be mounted side by side.

The paraboloid itself weighs approximately $5\frac{1}{2}$ tons; the frontal wind load for a 100 mph wind is about 40 tons. It is expected that winds of this force will be withstood.

The antenna is mounted atop Crawford Hill near Holmdel, New Jersey, at an altitude of 370 feet. It is aimed towards Pharsalia, New York, a distance of about 171 miles.

MEASUREMENT TECHNIQUE

The two important properties of the antenna which had to be determined before it could be put into use were its gain and radiation pattern at the operating frequencies of 460 mc and 4 kmc. It was also hoped to

Fig. 2 — Assembling the sectors.

Fig. 3 — The completed antenna.

Fig. 4 — Front view of the paraboloid.

Fig. 5 — Antenna scanning motors.

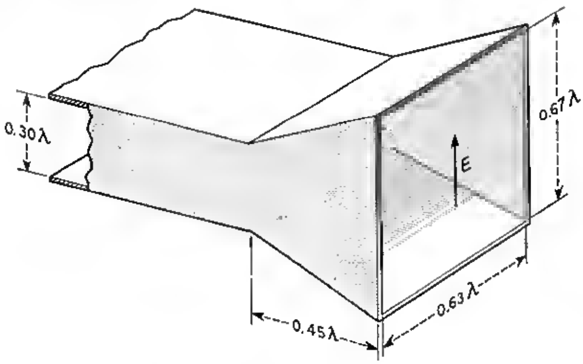

Fig. 6 — Feed horn dimensions.

measure these properties at 9.4 kmc to get some idea of how good the mechanical tolerances actually are.

The first requisite for making antenna measurements is a sufficiently uniform incident field. The source producing this field must be located at a distance of at least $2b^2/\lambda$, (b is the paraboloid diameter), which means a distance of about 0.6 mile at 460 mc, six miles at 4 kmc, and thirteen miles at 9.4 kmc. An obvious and convenient place for the sources was at Murray Hill, 22.8 miles away, which is on the transmission path to Pharsalia. Having located the sources at a suitable distance it was then necessary to test the incident field for uniformity. A 64-foot

Fig. 7 — Height run tower with the three standard horns during preliminary studies of the incident field.

tower was used for this purpose, and the variation of the incident field with height was measured before the antenna was erected. Figs. 7 and 8 show a typical set up. Height runs were taken at intervals of 15 feet along a line normal to the direction of transmission in the plane which would eventually contain the antenna aperture. The results of these tests showed that the Murray Hill location was satisfactory for the 4 and 9.4 kmc sources, with ground reflections giving rise to ± 1 db variations with height. In each case several complete cycles occurred in the 60-foot height run so that an average signal level could be established with an accuracy of a few tenths of db.

However, at 460 mc the variation with height was about 5 db, and only a portion of one cycle was available, so that the average signal could not be determined. The solution was to bring the source to a location as close as possible to the effective ground reflecting surface. Such a location was found at the far edge of a large body of water lying in the path, and the source antenna was placed in a mobile truck 10 feet above the water and eight miles away. The resulting variation with height was now only about 1 db.

In all cases the variation of field at right angles to the direction of transmission was found to be no worse than ± 1 db; thus it was felt that suitable sources for test at all three frequencies were now ready.

The standard method of measuring the gain of a microwave antenna is to compare the signal received from the antenna to that from another antenna whose gain is accurately known. A pyramidal horn of about 20 db gain is usually used as the standard. Such horns are readily available at 4 kmc and 9.4 kmc, and, in principle, also at 460 mc. Under the present set up, however, the physical dimensions of the standard horn were limited by the necessity of raising the horn on a carriage attached to the 64-foot tower. The largest horn that could be so mounted had an aperture of 4 feet $\times$ 4 feet, or 1.8λ on a side at 460 mc. Since the gain of a horn of this small aperture size cannot be accurately calculated by the usual formulas a scale model was made and tested at 4 kmc. The result of this test showed that the actual horn gain was 15.05 db, which is about 0.4 db more than the calculated gain.

A typical gain measurement on the 60-foot paraboloid was thus made as follows:

1. The feed position and antenna orientation were adjusted to obtain maximum received signal level.

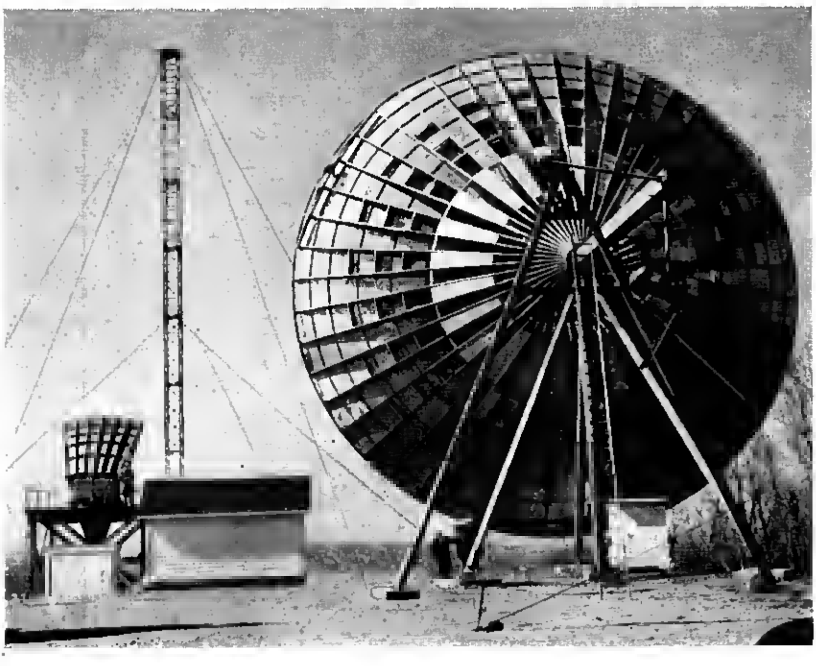

Fig. 8 — Position of height run tower during gain measurements.

2. The average incident field was determined by a height run with a standard horn.

3. The decibel gain of the antenna was then calculated by adding the db gain of the standard horn to the db difference in the signal levels determined in (1) and (2).

The problem of adjusting the 60-foot antenna for maximum received signal at 4 kmc and 9.4 kmc was complicated by the scintillations of the

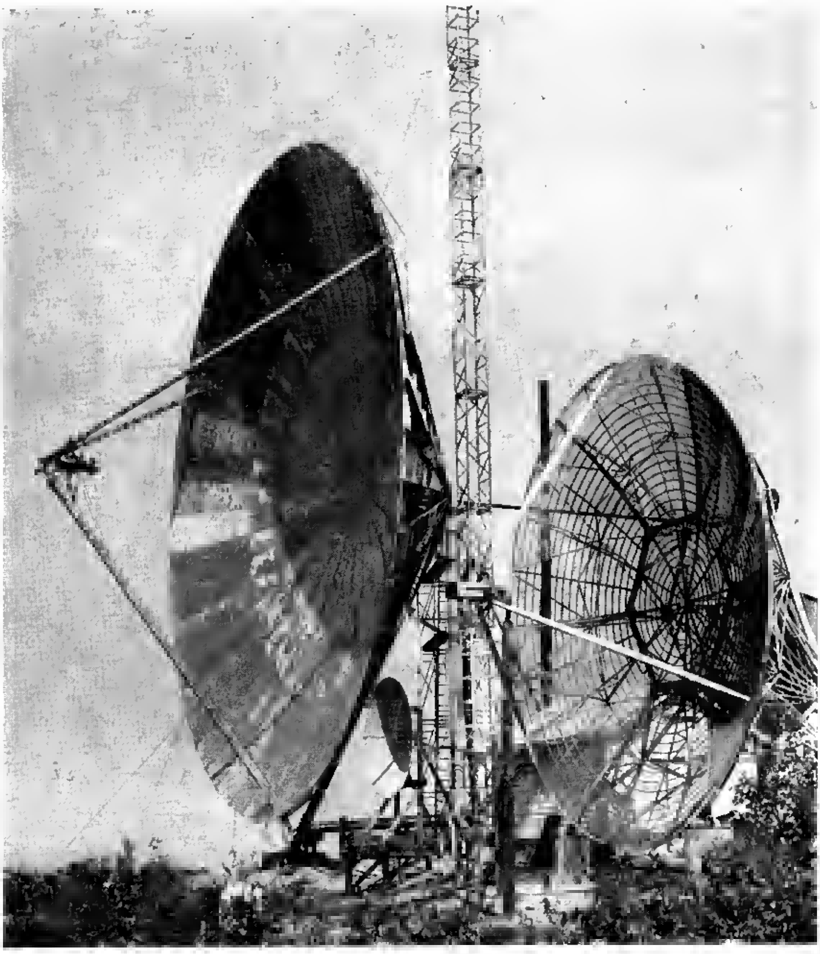

Fig. 9 — A view of the antennas at Crawford Hill used for beyond-the-horizon propagation studies and showing the 60-foot, a 28-foot and an 8-foot paraboliod, the latter between the two larger ones.

TABLE I

Frequency	Area Gain,* db	Gain, db Meas.	Ratio of Effective Area to Actual Area	3 db beam width		1st Minima	1st Minor lobes
				Calc.	Meas.		
460 mc	38.90	37.0 ± 0.1	0.65	2.35°	2.45°	—	—
3.89 kmc	57.44	54.6 ± 0.2	0.52	0.28°	0.3°	−33db	−23db
9.40 kmc	65.12	61.1 ± 0.5	0.40	0.12°	0.14°	−25db	−18db

* The area gain is defined as 10 log $\frac{4\pi}{\lambda^2}$, where A is the paraboloid projected area, 2,830 square feet.

incident field at these frequencies due to the remote location of the source. Accordingly, instead of adjusting the feed position for maximum signal level, it was adjusted to give vertical and horizontal radiation patterns having the best possible symmetry, deepest minima, and lowest minor lobes. It was then assumed that this was also the point of maximum gain. At 460 mc the scintillations were so small that the conventional technique of adjusting for maximum output was effective.

A double detection receiver was used for making all measurements. Signal level decibel differences were established by an attenuator in the intermediate frequency (65 mc) channel, and could be determined to an accuracy of ±0.02 db.

RESULTS

Carrying out the measuring procedure described above the results given in Table I were obtained. At 460 mc the restricted scanning range did not permit inspection of the minor lobes.

CONCLUDING REMARKS

The overall performance of this antenna is considered to be excellent. In general the radiation patterns are clean with satisfactory minor lobe structure. The good performance at 9.4 kmc (61 db gain) is particularly gratifying, since the mechanical tolerance of $\pm\frac{3}{16}$ inch is equivalent to $\pm\lambda/7$ at this frequency.

As stated earlier, this antenna was designed to provide a research tool for propagation studies and thus has some features which are neither necessary nor desirable in an antenna intended primarily for communication use. A consideration of the problem of providing a sturdy 60-foot

antenna for fixed point-to-point service led to the square "bill-board" design* and antennas of this type are now in production.

ACKNOWLEDGEMENTS

The construction of the antenna described in this paper was carried out under the general direction of H. W. Anderson, Supervisor of the Holmdel Shops Department. The paraboloid was assembled in place by members of the Carpenter Shop supervised by C. P. Clausen. Daniel Beaton, of Lorimer and Rose, served in an advisory capacity on some features of the construction. Assistance in the design and testing of the antenna was given by many members of the technical staff.

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* A picture and short description of this antenna appeared in Bell Laboratories Record, **34**, p. 37, Jan., 1956.